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CARBON FOOTPRINTING

Managing the carbon footprint of products: the contribution of the method composed of financial statements (MC3)

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Abstract
Purpose Carbon footprints (CF) provide companies, customers, and other agents with information related to greenhouse gas (GHG) emissions from the life cycle of products, identifying key points in the supply chain, potential risks, and opportunities of improvement. This paper briefly examines how the method composed of financial statements (MC3) (MC3, as coined from the name of the method in Spanish, i.e., *método compuesto de las cuentas contables.*) approaches to specific requirements related to the assessment of product GHG emissions, pointing out the contribution of this method to assessing and communicating the carbon footprint of products.
Materials and methods The MC3 was developed between 2000 and 2002 by J. L. Doménech who designed a tool for assessing ecological and carbon footprint of organizations. Nowadays, MC3 is supported by the Multi-University Working Group on Corporative Footprint. One of the recent achievements of this group has been the development of MC3 for products carbon footprinting. The MC3 approach has been recognized by the Spanish Observatory for Sustainability as a valid methodology for assessing and reducing GHG emissions arising from companies under the frame of the Spanish GHG Voluntary Reduction Agreement.
Results MC3 offers guidelines for assessing the CF of products. Guidelines include specific requirements for issues such as system boundaries, temporal boundaries, and goal setting. Information on specific issues such as emissions from land use change, capital goods or carbon storage clarifies the approach to be taken by organizations implementing product carbon footprinting.
Discussion Consumers and organizations all over the world are interested in obtaining information regarding the carbon footprint of products they consume and produce, being needed further standardization of methods for carbon footprinting. However, it is difficult that one approach provides for optimal results in a wide range of situations. MC3 is one of the existing approaches to assess the CF of products. MC3 has been developed under the premise of being a simple and practical method. The role of markets as the main source of communicating CF information on products among the members of the supply chain is an important strength of the method.
Conclusions MC3 provides for an internationally standardized method for the assessment of GHG emissions from the life cycle of products built on the LCA guidance and key principles of relevant approaches of the field of LCA. MC3 offers useful information for sustainable development, carbon management of organizations and sustainable consumption, being a flexible, transparent, and easy-to-apply method.

Keywords Carbon footprinting · GHG (greenhouse gas) assessment · LCA · MC3 (one of the existing approaches to assess the CF of products) · Supply chain

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1 Background

Environmental management at a corporate level is traditionally linked to the control of the direct (or onsite, immediate) impacts trying to establish measures that affect questions such as the consumption of resources or the generation of emissions and wastes (Doménech 2007). In the last years, different studies have highlighted the need to adopt an integral management of the environment, considering the entire chain of suppliers of companies (Krantz 2010; Munasinghe 2010; Sinden 2009; Wiedmann and Lenzen 2009).

Strategic cooperation among suppliers and systems thinking along interlinked value chains will allow companies obtaining environmental improvements, reductions of costs from reorganizing existing processes in the supply chain (Carbon 2008; Seuring 2004), competing along the entire life cycle of products and services (Krantz 2010).

From the point of view of consumers, environmental information of products is a need for making sustainable consumption decisions. The carbon footprint (CF) can be seen as a subset of the demand for environmental information that is being used for knowledge-based decision making in the context of sustainable consumption and production (European 2007). The demand of low CF products can be a key factor for stimulating innovation in businesses while driving political leaders to promote sustainable consumption (Munasinghe 2010).

In response to this interest, the method composed of financial statements (MC3) provides a solution for those companies interested in assessing and communicating organization and products carbon footprint.

This paper briefly examines the approach of MC3 to specific requirements related to the assessment of product GHG emissions, pointing out the contribution of this approach to assessing and communicating the CF of products.

2 Materials and methods

2.1 Development of the method

The MC3 was initially developed between 2000 and 2002 by biologist J. L. Doménech. The original method, including guidelines for assessing the CF of organizations, was published by the Spanish Association for Standardisation and Certification (AENOR) (Doménech 2007).

Four years later, Doménech led the Multi-University Working Group on Corporative Footprint in collaboration with five Spanish universities (Santiago de Compostela, Cantabria, Oviedo, Cádiz, and Valencia). From 2006 to 2008, this group focused on specific methodological questions. The Working Group established six working areas (materials, services, emissions and waste discharges, agricultural and fishing resources and forestry resources) carrying out seven pilot studies. In them, MC3 was applied to seven companies. Results of this research raised the quality of the method being published in several papers (e.g., Carballo-Penela 2009; Carballo-Penela et al. 2009; Coto et al. 2008). At this moment Multi-University Working Group is carrying out different pilot studies for obtaining unitary footprints for products.

Recently, the Spanish Observatory for Sustainability (SOS) has accepted the MC3 approach for assessing and reducing GHG emissions arising from companies under the frame of the Spanish GHG Voluntary Reduction Agreement.

2.2 Life cycle impact assessment

2.2.1 Selection of impact categories, category indicators, characterization models, and assignment of life cycle inventory results to the selected impact categories

The CF is still emerging and finding space in academic spheres, existing different interpretations about the gases whose emissions the indicator includes. In some research, CF includes several gases of greenhouse effect, expressing the indicator in equivalent tons of CO_2 (BSI 2008; Doménech 2004; European 2007; Sinden 2009). Others (Global Footprint 2007; Wiedmann and Minx 2008) consider exclusively only one gas, the CO_2.

These differences appear in existing definitions of CF. For the Global Footprint Network, CF includes the demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO_2) emissions from fossil fuel combustion (Global Footprint 2007, p. 1). The Carbon Trust states that CF includes the total emissions of greenhouse gases in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (Carbon 2007, p. 4). Wiedmann (2009) points out that CF should include all greenhouse gas emissions that can be associated directly or indirectly with an activity.

Under the view of the MC3, the inclusion of omissions from other GHG sources increases the utility of this indicator for those companies that have goals of emissions linked to the Protocol of Kyoto and future post-Kyoto international agreements.

The International Panel on Climate Change (IPCC) supply coefficients that allow transforming emissions from different gases into equivalent tons of CO_2 considering their global warming potential (GWP) (IPCC 2007) over there time horizons, 20, 100, and 500 year. These coefficients are the right tool for transforming non-CO_2 GHG emissions into CO_2 emissions.

The time horizon for the GWP is a relevant question to solve, since different gases have different residence times in the atmosphere. Choosing a 20-year time horizon would increase the importance of those short-lived GHG releases, while choosing a 500-year time horizon would lead decision making to a long-term vision, lessen the importance of short, and medium decision making (Sinden 2009, p. 199). Hence, the MC3 adopts a 100-year time horizon (Table 1).

Finally, since MC3 deals with a single impact category of global warming, results from life cycle inventory are assigned to this category.

2.2.2 Calculation of category indicator results

The origin of MC3 can be found in the Wackernagel's concept of household footprint and the matrix of consumptions versus land present in the spreadsheet for the calculation of households' ecological footprint (Wackernagel et al. 2000). In this way, Doménech (2004) prepared a similar consumption land use matrix, which contains the consumptions of the main categories of products needed by a company. The land use matrix also includes sections for the wastes generated and the use of land.

Companies' information on some consumption is hardly expressed in tons, while it is normally available in money expenditure. The conversion into mass units (tons) can be made by considering the specific product average prices in the period under study (for example, monetary unit/kg). Another option is to use foreign trade statistics, which offer information about imports and exports of the different tariff chapters expressed in monetary units and tons, thus enabling one to obtain a monetary unit/ton factor. Once the weight of every purchased product is known, MC3 uses energy intensities or unitary footprints of products and emission factors to transforms tons into GHG emissions.

Energy intensity factors indicate the energy consumed in the production of each product purchased by a company, expressed in gigajoules per ton (GJ/t). At present, these factors are mainly obtained from Ibañez Etxeburúa (2001), Mayor Farguell et al. (2003), and Simmons et al. (2006).

The energy incorporated in products is transformed into GHG emissions using emission factors (e.g., tCO_2/GJ) obtained from IPCC (2007). GWP coefficients (GWP) in a 100-year time horizon, make possible the transformation of GHG into equivalent tonnes of CO_2. Unitary footprints collect the GHG emissions/t product in every stage of the life cycle of a product. Footprints per tonne of product (unitary footprints, tGHG/t of product) are obtained dividing the total footprint of every company by its production.

Table 1 MC3 and mandatory element from ISO 14044:2006

Element	MC3 solution
Single impact category	Global warming
Category indicator	GWP of the emissions arising from the life cycle of a product
Characterization model	100-year time horizon GWP data

Source: own elaboration

2.3 Data

The CF of organizations is obtained by considering the consumed amount of every good and service purchased by companies in terms of mass units (kg, tons). The needed information to estimate CF using MC3 is mainly obtained from annual accounting documents such as the balance sheet and the income statement. This means that up-to-date footprints can be obtained every year.

By pointing out the purchased products, accounting documents clearly state the activities that are associated with every organization. Further information from other company departments with specific data about certain sections (e.g., waste generation) may also be necessary in case this information is excluded from the financial statements. The assessment of the CF of products does not require additional data, since unitary footprints are built on organization footprints.

2.4 The scope of MC3

The scope of MC3 is the assessment of GHG emissions arising from companies and products considering their life cycle. According to the view of MC3, carbon organization footprints include emissions from the production of all products consumed within an organization's factories. This includes materials used as inputs into the organizations production processes and consumed products within offices and other holdings needed to keep the organization running and any external activity required for the organization to do business.

As World Resources Institute (WRI)/World Business Council for Sustainable Development (WBCSD) (2004) states, MC3 distinguishes scope 1 emissions or the GHG emissions from sources owned or controlled by an organization; scope 2 emissions or indirect GHG emissions associated with the generation of electricity purchased by the organization; and scope 3 emissions, including all other indirect GHG emissions associated with the operations of the organization, e.g., the purchase of materials and products for consumption or manufacturing.

2.5 Goal of MC3

The goal of MC3 is the assessment of CF of organizations and products. In the first case MC3 provides companies with an

inventory of materials, goods, services, and generated wastes, transformed into a common unit, equivalent tCO_2. Products' CF includes GHG emissions arising from their life cycle. This information is useful for both managers and consumers demanding GHG information of products.

2.6 Contribution of MC3 to GHG emissions assessment

2.6.1 Overview

MC3 builds on the LCA guidance and key principles of relevant approaches of the field of LCA, including ISO 14040: 2006 and ISO 14044: 2006. Questions such as the selection of impact categories, category indicators, characterization models, assignment of life cycle inventory results to the selected impact categories; and calculation of category indicator results (AENOR 2006) are taken into account by MC3. With regard GHG assessment, MC3 fulfill requirements under ISO 1464-1:2006, IPCC publications (IPCC 2007), the GHG Protocol (World Resources Institute WRI/World Business Council for Sustainable Development WBCSD 2004, 2009) and the Spanish GHG Voluntary Reduction Agreement (Spanish Observatory for Sustainability SOS and Spanish Ministry of the Environment and Rural and Marine Affairs MERAM 2007).

However, MC3 is not based on conventional process-based LCA, adopting an organization-based LCA (Carballo-Penela 2009). The adoption of MC3's life cycle approach requires establishing links among the CF of the different companies of the studied supply chain. When each of the participants in the life cycle of a product acquires different goods from the company situated in the previous phase, they are also acquiring the footprint incorporated in that good. If every participant communicates the GHG emissions/t of the goods and services that produces to the following phase of the supply chain, the needed connection is made.

These unitary footprints come from pilot studies carried out by the Multi-University Working Group on Corporative Footprint. The pilot studies are based on the energy intensities usually used by the MC3 (Carballo-Penela, et al. 2009) besides results from other life cycle studies that estimate the emissions of CO_2 or the demand of surface from primary data (e.g., Ibañez Etxeburúa 2001; Mayor Farguell et al. 2003).

When a company acquires a product, the purchase documents should include the unitary footprint accumulated until that moment and making possible to use that information for estimating its organization footprint. If a supplier does not provide information on a product, MC3 database will supply this information. This database includes the unitary footprints on standard life cycles for the main categories of products under the tariff classification of merchandise (US Department of Homeland Security 2004). Unitary footprints show information from the different stages of the supply chain.

This way of estimating CF avoids double counting problems with some intermediate inputs, a relevant question in this context (Global Footprint 2006, 2009). Organization footprints are useful in terms of making decisions on improving environmental performance of organizations but never in terms of aggregating environmental impacts. This aggregation is only possible in terms of the footprint of products.

Communication of the environmental and economic information in the same documents makes the integration of the first in the markets possible in a natural way. This approach avoids high communication costs, making possible that markets become a powerful force for delivering environmental improvement.

3 Results

3.1 Obtainable results with MC3

MC3 produces different types of results. Firstly, organization's CF include GHG emissions from sources owned or controlled by the organization. They are useful in terms of providing an inventory of materials, goods, services and generated wastes, transformed into a common unit, equivalent tCO_2 (Table 2). This information can be used for environmental policies and corrective measures based on the CF at an organizational level.

A second use of CF is linked with assessing the CF of products considering their life cycle (Table 3). At this level, the MC3 assesses GHG arising from a life cycle perspective of goods and services. As Sinden (2009) remarks, there are a wide range of uses for information on the CF of products. This indicator facilitates the evaluation of alternative products configurations and supplier selection on the basis

Table 2 An example of organization's CF: the case of a cannery company

Category of product	Total	% Total CF
Energy	571.4	2.0
Materials	5,170.1	18.3
Services	55.0	0.2
Waste	778.1	2.7
Agricultural and fishing resources	19,375.6	68.5
Forest resources	2,270.3	8.0
Water	57.9	0.2
Total	28,278.3	100.0

CO_2-equivalent emissions (tCO_2-e). Source: Carballo-Penela (2009)

Table 3 An example of product's CF: the CF of canned mussels

Supplier company	CF	
	tCO_2-e/t of mussels	Added tCO_2-e/t mussels
Mussel producer	0.3	0.3
Processor company	3.6	3.3
Cannery company	10.4	6.8
Retailer	10.8	0.3
Total	10.8	10.8

CO_2-equivalent emissions (tCO_2-e). Source: Carballo-Penela (2009)

of the life cycle GHG emissions associated with goods and services at an internal level (Sinden 2009, p. 197).

In terms of internal decisions, products' footprints enable making decisions on reducing product and companies' CF. This allows for obtaining product differentiation, helping to achieve global sustainable development.

From consumers' point of view, MC3-based ecolabels provide an opportunity for considering GHG when making purchasing decisions. Consumption of low-carbon products and services can encourage politicians to take radical steps toward a lower carbon world (Munasinghe 2010, p.5).

3.2 System boundaries and the extent of life cycle[1]

MC3 is based on the cradle-to-gate life cycles, sometimes referred to as Business-to-Business (B2B) life cycles. This means that MC3 assesses CF from the raw materials phase to the retailing phase, by including all the activities required to extract the raw materials for the product, manufacture the product, and ship the product to the point of purchase. Use and disposal emissions are outside the boundary of MC3. MC3 collects the GHG emissions of all the products acquired by every company and the generated wastes in each of the studied phases of the life cycle.

3.2.1 Use and disposal emissions

The inclusion of GHG emissions from the use and disposal stages of products in CF analysis proved to be a significant cause of concern for carbon footprinting (Sinden 2009). Emissions from the use and disposal of products by the users are outside the boundary of MC3.

The goal of MC3 is to communicate GHG emissions from the production of goods and services under the premise that this information can be useful for achieving sustainable production and consumption and, in extension sustainable development.

[1] For further information, please see European Commission (2010); Kim et al. (2009); BSI (2008); Frischknecht et al. (2007) or IPCC (2000).

CF information should encourage companies to integrate sustainability principles into the core of their business. Available information should allow them for capturing savings from resource efficiencies both in their own operations and along their value chain. Competition on innovation for sustainability, eco-efficiencies and green consumer markets are key opportunities for future success (Krantz 2010). Information for consumers should allow them to demand low-carbon products.

Use and disposal emissions of products depend on both, technical characteristics of the product and the use of the product by the user. Technical characteristics of products are relevant for those goods whose use generates GHG emissions (e.g., a car) but not always for the rest of goods (e.g., food). This specific information can be showed, as it is really occurs, in specific labels or other guides provided by retailers.

On the other hand, the use and disposal of products are highly variable depending on the user of the product. This fact makes difficult obtaining accurate information of associated emissions. In addition, supply companies have limited influence in changing use behavior (Carbon Trust 2007). Best use guidelines for the use of goods should be delivered with the product, but they are outside the boundaries of MC3. This exclusion also avoids establishing a temporal boundary for GHG future emissions associated with the use stage of a product.

3.2.2 Capital goods emissions

There is yet no clear idea about the role of capital goods LCA. Some LCA case studies exclude capital goods form the assessment. On the other hand, some studies confirm that certain products (e.g., phtovoltaic and wind electricity) are much affected by capital goods contributions, no matter which indicator is chosen (Frischknecht et al. 2007). With regard to CF analysis, Doménech (2007) states that emissions from capital goods make a relevant contribution to the CF of products.

MC3 includes emissions from capital goods. The CF of capital goods is estimated allocating the total amount of GHG emissions generated in their production, considering the duration of their expectable life. This is the way to avoid high fluctuations of the footprint in the periods when capital goods are acquired.

3.3 Temporal boundaries and delayed emissions

3.3.1 Carbon storage

Some products (e.g., wood-based products) have the ability to retain carbon of biogenic or atmospheric origin in a form other than as an atmospheric gas. This kind of products

could receive a benefit in terms of carbon footprinting for retaining what was previously atmospheric carbon in solid form. Weighting the GWP of biogenic carbon released by the product by the proportion of years within the 100-year assessment period that the biogenic carbon is in the atmosphere (Sinden 2009 p. 200) is a valid way of approaching this issue.

Calculation of the carbon storage of products introduces requirements considering issues such as the fate of the products over a 100-year period (e.g., being burnt, recycled or remaining as the original product); the amount of carbon released as CO_2 over the 100 years, and the moment of the release (BSI 2008).

These additional requirements increase the complexity of the CF assessment, which can affect the accuracy and simplicity of the analysis. Therefore, MC3 do not consider any benefit related with carbon storage.

3.3.2 Land use change

Emissions of GHG due to changes in land use mainly come from converting non-agricultural land to agriculture use. In this context, land use change emissions can strongly affect agriculture and biofuel products' CF.

However, land use change studies not always consider many of the potentially important variables that might affect the greenhouse gas emissions of biofuels. Greenhouse gas emissions associated with indirect land use change depend strongly on assumptions regarding social and environmental responsibilities for actions taken, cropping management approaches, and time frames involved, among other issues (Kim et al. 2009).

At this moment, MC3 do not consider emissions from land use change. With regard to emissions arising from direct land use change, this decision will be revised in the next annual meeting of the Multi-University Working Group on Corporative Footprint, scheduled for the 21st of December 2010.

3.4 Offsetting

Offsets are not within the boundary of the assessment since they occur out of the life cycle of products. However, MC3 provides guidelines for this kind of assessment (Carballo-Penela 2009; Doménech 2007).

Companies interested in offsetting emissions from a product can invest in land capable of absorbing CO_2 emissions, despite the desirable reduction of their footprint by being more efficient and by curbing consumption (Carballo-Penela et al. 2009). In the case of forest land, an average absorption rate of 3.7 CO_2 t/ha/year is suggested (IPCC 2007). Multi-University Working Group on Corporative Footprint is at this moment carrying out a pilot study to establish average absorption rates with regard to pastures, croplands or other land capable of absorbing CO_2 emissions.

4 Discussion

Nowadays, different standards like ISO 14040, ISO 14044 or Global Footprint Network Standards, contain guidelines for the assessment of the CF from the life cycle of products. Forthcoming ISO 14067-1 on carbon footprinting and WRI/WBCSD standards should also contribute to the standardization of the analysis.

These standards provide sufficient flexibility to allow different approaches to suit the specified requirements they contain. Approaches based on input–output analysis (Wiedmann 2009; Wiedmann and Lenzen 2009), process-based LCA (BSI 2008; Sinden 2009), or organization-based LCA (Carballo-Penela 2009) are used to estimate the CF of products at this moment. Even though they share similar objectives, there are relevant differences in terms of the calculation method and some assumptions involved in the estimation of the indicator: the CF of a product will be quite different depending on the approach chosen.

There are different reasons that encourage an internationally agreed approach to CF analysis. Consumers and organizations all over the world are interested in obtaining information regarding the CF of products they consume and produce. Secondly, globalization processes of production and consumption tend to break national borders in terms of producing and purchasing products. However, global consensus about one methodology is not probable in the short-term, since it is not clear who should lead this process and the way to do it. On the other hand, all the available approaches have weaknesses and strengths being difficult that one approach provides for optimal results in a wide range of situations (Table 4).

In this context, research to transform the GHG emissions obtained from different methodological approaches that suit the specified requirements from international standards into equivalent CF could be more useful than debating about choosing one. Doing this, CF information could be standardized.

4.1 Strengths of the method

In this paper we introduce one of the existing approaches, the MC3. MC3 provides complete CF for organizations, products using an organization-based LCA. This approach has been developed under the premise of being a simple and practical method for carbon footprinting (Finkbeiner 2009) and internationally applicable.

Table 4 The MC3 and others methodological approaches

Concept	Input–output Techniques	PAS 2050	MC3
Calculation method	Input–output analysis/	Process LCA	Organization based LCA
Activities included in CF	All the activities by an organization	All the production activities	All the activities by an organization
Source of information	Basically, financial accounts	Maps of processes/LCA inventories	Basically, financial accounts
Transformation of financial information into mass unit data	No needed. The method uses monetary input–output coefficients	No needed	Needed. Explicit method

Source: own elaboration

MC3 is a complete method, which collects the CF from the consumption of all goods and services and wastes generated by a company. It is a technically feasible method. Its calculation does not require extensive expert staff inputs: everybody working with spreadsheets is able to calculate CF.

Information from accessible financial documents clearly delimits the products and activities under analysis. The role of markets as the main source of communicating CF information on products among the members of the supply chain, thereby absorbing environmental performance as a competitive issue, is an important strength of the method (European Commission 2010).

MC3 is a transparent method. The spreadsheet and all the data needed for the estimation of CF, including energy intensity and emission factors, are available for researchers at http://www.huellaecologica.com.

The fact that the information comes from accessible financial documents and that each company covers a complete phase of the life cycle implies lower economic and time costs, besides delimiting clearly the products and activities under analysis. It also implies that MC3 does not need to separate between primary data and secondary data, deciding cut-offs criteria for excluding emissions from any specific activity, or dealing with allocation problems of coproducts.

The theoretical presentation of the method requires determining the participants in the life cycle. In practice, each company obtains the environmental information of the purchased products from their suppliers or from the MC3 database.

The way of estimating the CF avoids double counting problems with certain intermediate inputs. Organization footprints are useful in terms of making decisions on improving environmental performance of organizations but not in terms of aggregating environmental impacts. This aggregation is only possible in terms of the products.

4.2 Weaknesses

On the other hand, MC3 analysis is less detailed than conventional process-based life cycle assessment. The organization's activities are not divided into detailed simple processes that show the amount of energy and materials consumed at each stage of production. Instead, MC3 includes all the goods, services, and waste consumed or generated for the organizations in a period. The use of unitary footprints or energy intensities and other aggregated information allows MC3 to estimate the CF.

MC3 does not avoid double counting problems when companies acquire a product that incorporates materials produced by them. The footprint analysis reference period is usually one year, which is considered sufficient time for producing a product used by another organization to produce goods that come back to the first company—for example, the case of a steel producer using trucks made from their own steel (Global Footprint 2006). MC3 allows for correction of this kind of double counting problem when identified, although systematic correction systems should be developed.

5 Conclusions

Sustainability of products is a key societal challenge and is of increasing importance for business and consumers. Providing for the next generations of sustainable consumers presents both opportunities and challenges for companies, organizations, and governments (Krantz 2010). On the other hand, consumers need simplified, relevant an accessible environmental information to make sustainable choices (Munasinghe 2010).

MC3 provides for an internationally standardized method for the assessment of GHG emissions from the life cycle of products built on the LCA guidance and key principles of relevant approaches of the field of LCA. MC3 offers useful information for sustainable development, environmental management of organizations and sustainable consumption, being a flexible, transparent, and easy-to-apply method.

MC3 is supported by the Multi-University working Group on Corporative Footprint. The continuous work of this group has been useful to MC3 be recognized by the

Spanish Sustainability Observatory as a valid approach for the assessment of the CF of organizations under the frame of the Spanish GHG Voluntary Reduction Agreement.

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